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(54) **Plate type reformer.**

(57) Main units (I, I), which include a reforming reactor (16) and a combustor (20), both piled together having a heat conductive partition wall (22) therebetween, are located in a manner such that the combustor (20) sides of the main units (I, I) face each other, with an auxiliary unit (II) for supplying fuel to each combustor (20) being put between the main units (I, I). Raw material gas to be reformed is supplied to the reforming reactor (16) through a passage (36, 40) formed in each unit (I, II), and then discharged through another passage (38, 42) formed in each unit (I, II). Fuel is supplied to the auxiliary unit (II) through another passage (46, 52) formed in the main unit (I) so that it may flow uniformly dispersing in the combustor (20) via the auxiliary unit (II).

FIG. I

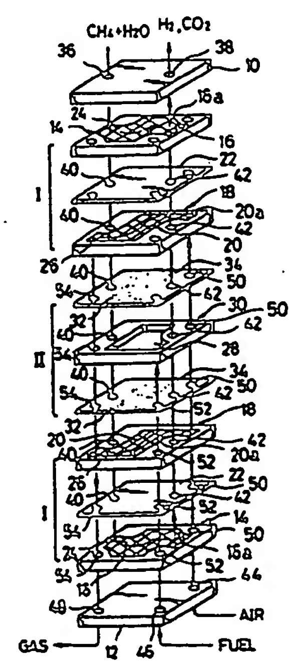

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Plate Type Reformer

This invention relates to a reformer where fuel gas (raw material gas) is reformed to product gas and supplied to anodes (fuel electrodes) of cells in fuel cell systems, in particular, and relates to a plate type reformer where reforming reaction is conducted while the fuel gas is indirectly heated by burning gas which is supplied to cathodes (air electrodes) of the cells.

A fuel cell system is an electricity generating system using reversed electro-chemical reaction of an electrolysis of water in electrolytes including carbonates, phosphorates, etc., with hydrogen gas being supplied to anodes (fuel electrodes) and burning gas (O_2, CO_2) to cathodes (air electrodes) in the cells.

The hydrogen gas, which is supplied to the anode, is obtained by supplying fuel gas, such as methane, as raw material gas with the steam to the reformer, in accordance with reforming reaction which is given by the following chemical equation with catalysts:

$$CH_4 + H_2O \rightarrow CO + 3H_2$$
$$CO + H_2O \rightarrow CO_2 + H_2$$

To maintain the reforming temperature in the reformer, remaining hydrogen or carbon monoxide in the anode gas is supplied to the reformer and burned there to heat up indirectly the fuel gas to be reformed.

In such a reformer, however, air and fuel flow into a combuster of the reformer to be burned together, so that volume of the combuster has to be large, and the reformer is often too large in size. The temperature of the burned gas is as high as 1300 degrees C until heat is transferred to the reforming gas and it is structurally impossible to decrease the temperature of the burnt gas in order to match the temperature of the heat receiving gas (between 550 and 750 degrees C).

To solve these problems, plate type reformers which are compact in size, and in which uniform combustion all over the combustor is possible to achieve effective reforming, were recently proposed (see for example, Japanese Patent Application Laid Open No. 160136/1987).

A primary object of this invention is to provide a plate type reformer which enables an effective heat exchange between the burning gas and a raw material gas to be reformed at a lower temperature as hereinbefore possible.

A further object of this invention is to provide a plate type reformer which enables uniform fuel supply to the combustor as well as step-by-step combustion.

This invention provides a plate type reformer comprising plural main units which include a combustor filled with a combustion catalyst and a reforming reactor filled with a reforming catalyst, piled together with a heat conductive separator between the combuster and the reactor, and plural auxiliary units to supply fuel to the combustors of the respective main units.

Further this invention provides a plate type reformer in which the combustor-side surfaces of the main units face each other, sandwiching an auxiliary unit therebetween, thus the main units and the auxiliary unit are piled together, and this pile has a passage to supply air for combustion to the above-mentioned combustor, a passage to exhaust burnt gas from the combustor, a passage to supply the raw material gas to be reformed into the reforming reactor, a passage to draw off the reformed gas, and a passage to supply fuel to the above-mentioned distance plate.

The invention will be further described with reference to the drawings in which

Fig. 1 is a perspective view showing a part of an embodiment of this invention prior to assembling thereof;

Fig. 2 is a cross sectional view of Fig. 1 as assembled;

Fig. 3 and Fig. 4 illustrate temperature distributions of combustion gas and reforming gas between the inlet and the outlet of the reforming reactor during heat exchange, respectively;

Fig. 5 is a cross section view of another embodiment at its central part.

As described in Fig. 1 and Fig. 2, a single segment of a plate type reformer of this invention mainly comprises two main units I, in which a reforming reaction and a combustion take place, and one auxiliary unit II, through which fuel for combustion is supplied to the main units I, with the auxiliary unit sandwiched by the main units I, and the main units I being symmetrical to each other. Holders 10 and 12 are located on the exposed sides of the main units I, respectively.

The main unit I includes a reforming plate 14 in which a reforming reactor 16 is provided, a combustion plate 18 in which a combustor 20 is provided, and a heat conductive separator or a heat conductive partition wall 22 located between two plates 14 and 18. A central portion of the reforming plate 14 is hollowed out and the hollow or space 16a is filled with a reforming catalyst 24 so as to form the reforming reactor 16. Similarly to the reforming plate, a central portion of the combustion

plate 18 is hollowed out, and the hollow 20a defined within the combustion plate 18 is filled with a combustion catalyst 26 so as to form the combustor 20.

The auxiliary unit II comprises a distance plate 30 which has a scooped space 28, and two dispersion plates 34 which have a plurality of pores 32 to supply fuel from the scooped space 28 to the combustors 20 in the main units I, with the dispersion plates being stacked onto the distance plate.

In the pile of these main units I and the auxiliary unit II, the combustion plates 18 of the main units I are located to contact with the upper and lower dispersion plates 34 of the auxiliary unit II, respectively. The upper holder 10 and the lower holder 12 for the sandwich of the upper main unit I, the auxiliary unit II, and the lower main unit I are fastened by bolts and nuts, or the like (not shown).

The upper holder 10 has an inlet opening 36 for raw material gas to be reformed (CH_4 + H_2O), and an outlet opening 38 for the reformed gas (H_2, CO_2). The inlet 36 communicates with the reforming reactor 16 in the reforming plate 14 located thereunder, and the raw material gas to be reformed is supplied to the reforming reactor 16 in the lower main unit I through bores 40 formed within the partition plate 22, the combustion plate 18, the dispersion plate 34, and the distance plate 30. The gas so reformed flows through openings 42 formed within the partition plate 22, the combustion plate 18, the dispersion plate 34, and the distance plate 30 so that it encounters the gas reformed in the reforming reactor 16 in the upper main unit I and proceeds to the outlet opening 38 at the upper holder 10.

The lower holder 12 has an air inlet 44, a fuel inlet 46, and a burnt gas outlet 48. Air through the air inlet 44 is supplied to the combustion chamber 20 in the combustion plate 18 through openings 50 provided in the reforming plate 14 and the separator 22 of the lower main unit I, and then from that combustion chamber 20 the air is supplied to another combustion chamber 20 in the upper main unit I through openings 50 of the upper and lower dispersion plates 34 and the distance plate 30.

Fuel through the fuel inlet 46 is supplied to the scooped space 28 of the distance plate 30 via openings 52 bored within the reforming plate 14, the partition plate 22, the combustion plate 18, and the dispersion plate 34 of the lower main unit I.

Exhaust gas generated in the combustor 20 in the upper main unit I flows through holes 48 formed in the dispersion plate 34 and the distance plate 30 and encounters the exhaust gas generated upon combustion in the combustion chamber 20 of the lower main unit I. After that, those exhaust gases are discharged from an exhaust opening 48 through holes 54 provided in the lower partition plate 22 and in the lower reforming plate 14.

In the above-mentioned system, air is supplied through the air inlet 44 while fuel is supplied through the fuel inlet 46 in the lower holder 12, and raw material gas to be reformed (CH_4 + H_2O) is supplied through the gas inlet 36 in the upper holder 10.

The air flows from the air inlet 44 through the holes 50 into the combustors 20 in the upper and lower main unit I. The fuel flows into the scooped space 28 in the distance plate 30 from the fuel inlet 46 of the lower holder 12, through the fuel passage 52 of the main unit I, and then the fuel flows out of the scooped space 28, proceeding through the pores 32 of the upper and lower dispersion plates 34 into the upper and lower combustors 20 next to the dispersion plates 34. The fuel is burned with the combustion catalyst 26 in the combustors 20, and the resulting exhaust gas is discharged from the exhaust gas outlet 48 of the holder 12 through the holes 54.

On the other hand, the raw material gas to be reformed and supplied from the inlet 36 of the upper holder 10 flows into the reforming reactor 16 of the upper main unit I, and a part of the gas further flows into the reforming reactor 16 of the lower main unit I through the holes 40. This fuel gas is heated by the gas which has been burned in the combustor 20 and reaches the reaction chamber 16 through the separator 22, and is reformed to H_2 and CO_2 with the reforming catalyst 26 in the reforming chamber 16. The gas thus reformed is delivered outside the unit from the reformed gas outlet 38 of the upper holder 10 via the openings 42.

In the reforming process mentioned above, this system can be made compact because the reforming reactor 16 is located adjacent to the combustor 20 with the separator 22 disposed between the reforming reactor 16 and the combustor 20 so that the reforming reactor 16 may be heated up by the burned gas generated in the combustor 20.

Since the fuel flows through the scooped space 28 of the distance plate 30 and the pores 32 of the dispersion plate 34, it spreads uniformly throughout the combustor 20, and the combustion of the fuel takes place gradually or step by step, lowering the combustion temperature compared with conventional systems. It is possible to adjust the combustion temperature required by the heat receiving gas, by controlling the size and the pitch of the pores 32 in the dispersion plate 34.

Fig. 3 and Fig. 4 depict temperature distribution curves of burnt gas and heat-receiving reformed gas between the entrance and the exit of the reforming reactor, in which "X" indicates a temperature distribution curve of combusted gas, and "Y" indicates the distribution curve of the gas

reformed according to the present invention while "Z" is the temperature distribution curve of the gas combustion in a conventional system. Fig. 3 depicts distribution curves of the case where the heat exchange between combusted gas and heat receiving (reforming) gas is performed by parallel gas flow (co-flow), and Fig. 4 depicts the case of counter flow. As indicated by the curve Z, the temperature of the combusted gas in the conventional system is as high as 1300° C at the entrance while, according to the present invention, the burned gas temperature is 650° C at the entrance and 850° C at the exit as illustrated by the temperature distribution curve X. This means that a lower temperature can be used in the present invention.

Fig. 5 shows another embodiment of the present invention. This embodiment, basically identical with the example illustrated in Figs. 1 and 2, has two porous plates 60, each contacting to the combustor 20 side of dispersion plate 34 of the auxiliary unit II. In this example, the function of the porous plate 60 is to further disperse the fuel flowing into the combustor 20 from the pores 32 of the dispersion plate 34. In other words, if the size and the pitch of the pores 32 in the dispersion plate 34 are determined so as not to be affected by pressure fluctuation of the fuel, the pitch becomes too large and a uniform fuel dispersion is difficult to realize. In such a case, the porous plate 60 effectively serves to make the fuel much finer.

The present invention is not restricted to the above-mentioned examples but, for instance, the positions of the passages for air, fuel, etc. and of each inlet/outlet opening for fuel, the reformed gas, etc., may be changed from the positions shown in the figures. The numbers of layers of the main unit may be more than two, and accordingly, the number of auxiliary units will be increased.

Claims

1. A reformer including a reforming reactor (16) in which a raw material gas undergoes a reforming reaction in the presence of a catalyst and fuel gas is burned so that the reforming reaction temperature may be maintained at a proper level, and the burned gas may indirectly heat the raw material gas in the reforming reactor (16), **characterized** in that said reformer comprises: a plurality of main units (I), each main unit (I) including a combustor (20) filled with combustion catalyst (26) and a reforming reactor (16) filled with reforming catalyst with a heat conductive partition wall (22) being sandwiched between the combustor (20) and the reforming reactor (16); an auxiliary unit (II) having a fuel chamber (28) through which fuel is supplied to each combustor (20) of the main units (I), the combustor (20) sides of the main units (I) facing each other so as to sandwich the auxiliary unit (II) between the main units (I); an air passage (44, 50) for supplying air to said combustor (20); an exhaust passage (48, 54) for discharging the gas burned in said combustor (20); a fuel gas passage (36, 40) for supplying fuel gas for reforming to the reforming reactor (16); a gas discharge passage (42, 38) for discharging the gas which is reformed; and a fuel passage (46, 52) for supplying the fuel to said fuel chamber (28), all the passages (38, 40, 42, 44, 46, 48, 50, 52) being formed within the main and auxiliary units (I, II).

2. The reformer of claim 1, **characterized** in that the main units (I) are located on both sides of the auxiliary unit (II) in a way that the combustor (20) of each main unit (I) faces the auxiliary unit (II), and two holders (10, 12) are provided at the exposed sides of the main units (I), so that all the units (I, II, I) between the holders (10, 12) are piled together as a single unit.

3. The reformer of claim 1 or 2, **characterized** in that the main unit (I) includes a reforming plate (14) in which the reforming reactor (16) is formed, a combustion plate (18) in which the combustor or a combustion chamber (20) is formed, and a heat conductive partition plate (22) which is sandwiched between the reforming plate (14) and the combustion plate (18).

4. The reformer of claim 3, **characterized** in that the reforming reactor (16) includes the reforming plate (14) which is hollowed out at the center thereof, the hollowed space (16a) being filled with the reforming catalyst (24).

5. The reformer of claim 3 or 4, **characterized** in that the combustor (20) includes the combustion plate (18) whose central portion is hollowed out, the hollowed space (20a) being filled with the combustion catalyst (26).

6. The reformer of any one of the foregoing claims, **characterized** in that the auxiliary unit (II) includes a distance plate (30) which has a scooped space (28) that serves as a fuel supply chamber (28), and two dispersion plates (34, 34) disposed on both sides of the distance plate, a plurality of pores being formed in the dispersion plate (34) so that fuel is supplied therethrough from the fuel chamber (28) to the combustor of the adjacent main unit (I).

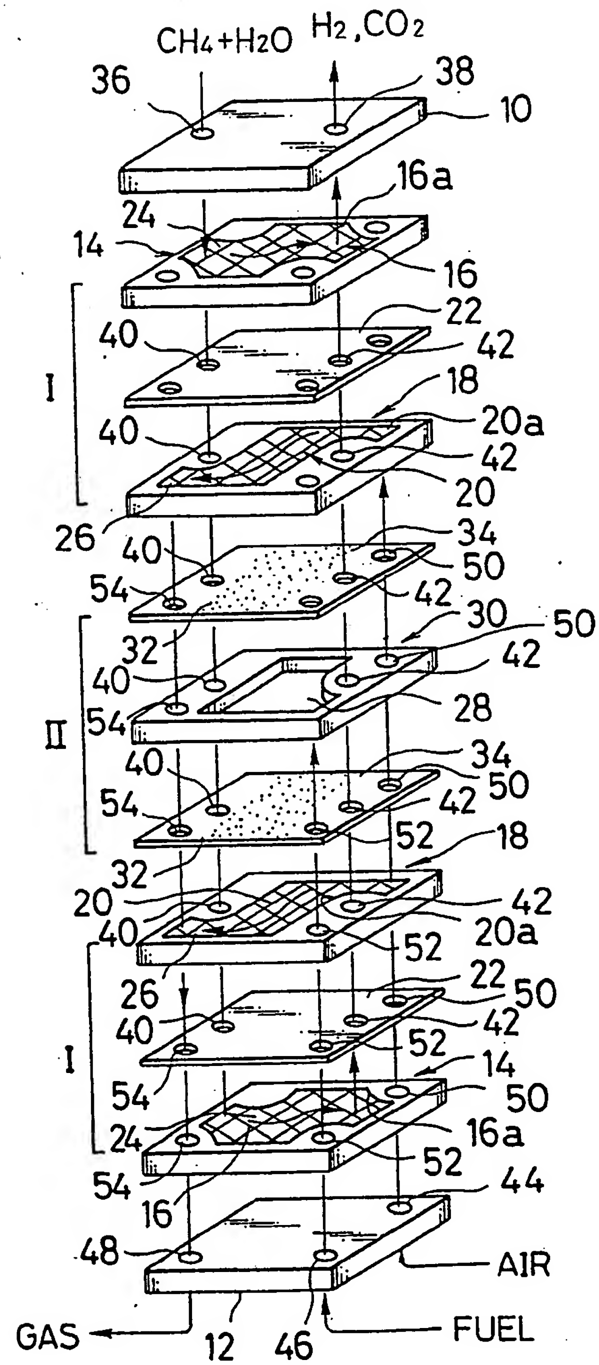
7. The reformer of claim 6, **characterized** in that the main unit (I) is stacked in a manner such that the combustor (20) of the main unit (I) may be located adjacent to the dispersion plate (34), and that a holder (10, 12) is mounted on the reforming reactor (16) side of the main unit (I) so that all the units (I, II, I) may be piled as a sing a element.

8. The reformer of claim 7, **characterized** in that the raw material gas inlet (36) and the reformed gas outlet (38) are formed in one holder (10), and that supply and discharge passages (40, 42) for raw material gas to be reformed and for the reformed gas are formed in the heat conductive partition wall (22), in the combustion plate (18), in the distance plate (30) and in the dispersion plate (34) of the auxiliary unit (II).

9. The reformer of claim 7, **characterized** in that the inlet openings (44, 46) for combustion air and fuel gas, and the outlet opening (48) for the combusted gas are formed in the other holder (12), that a supply passage (44) for combustion air and a discharge passage (54) for the exhaust gas are formed in the heat conductive partition wall (22), in the reforming plate (14), in the distance plate (30) and in the dispersion plate (34) of the auxiliary unit (II), and that a supply passage (52) is formed in the combustion plate (18), in the heat conductive partition wall (22), in the reforming plate (14), and in the dispersion plate (34) of the auxiliary unit (II), so as to allow the fuel gas to flow into the scooped space (28) of the distance plate (30).

10. The reformer of claim 6, **characterized** in that a porous plate (60) is provided on the combustor (20) side of the dispersion plate (34) in the auxiliary unit (II).

FIG.1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36
38
10
16a
24
14
16
22
40
42
I
18
20a
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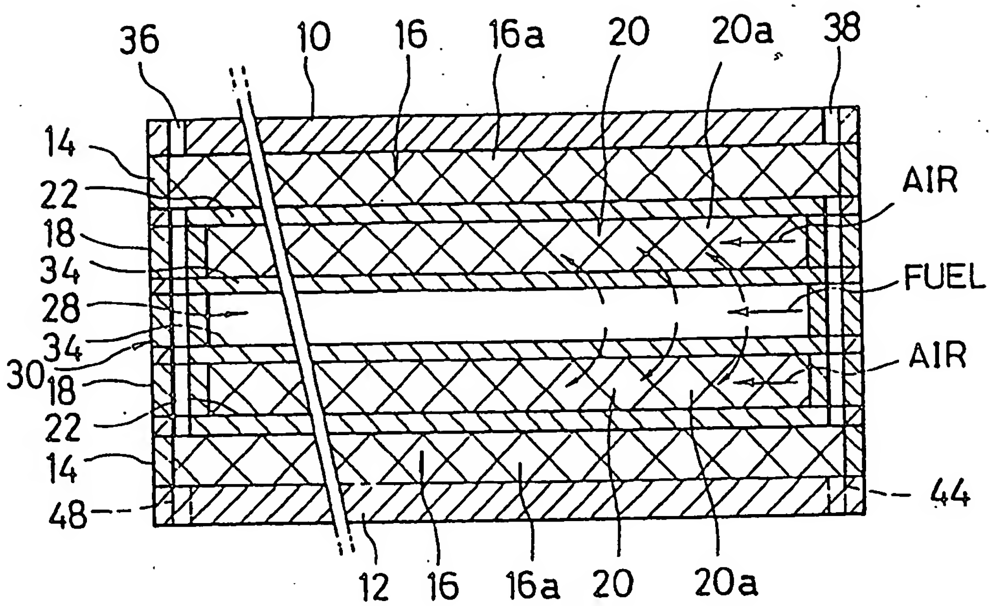
26
34
50
54
30
32
28
II
52
44
48
AIR
GAS
12
46
FUEL

FIG.2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10
16
16a
20
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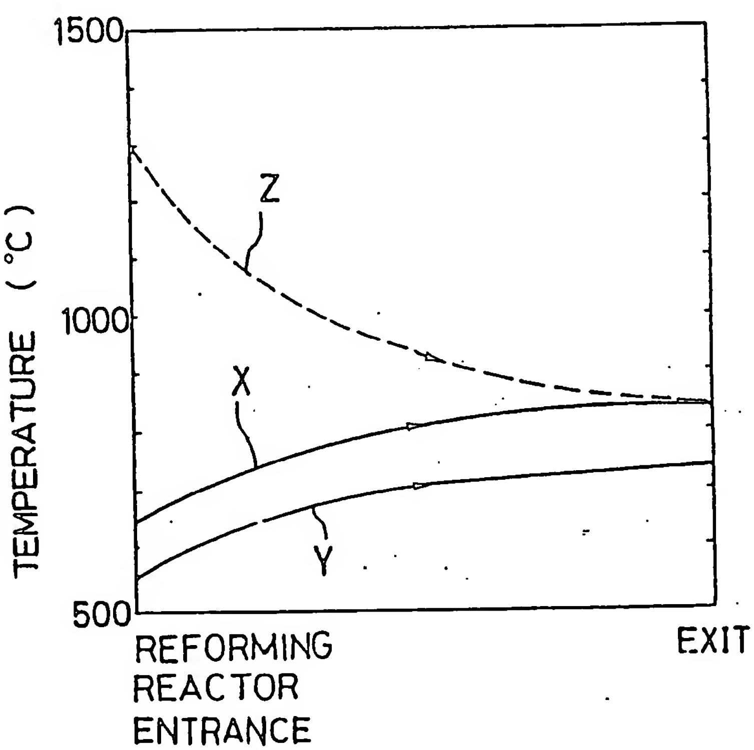
38
14
22
18
34
28
34
30
18
22
14
48
AIR
FUEL
AIR
44
12
16
16a
20
20a

FIG.3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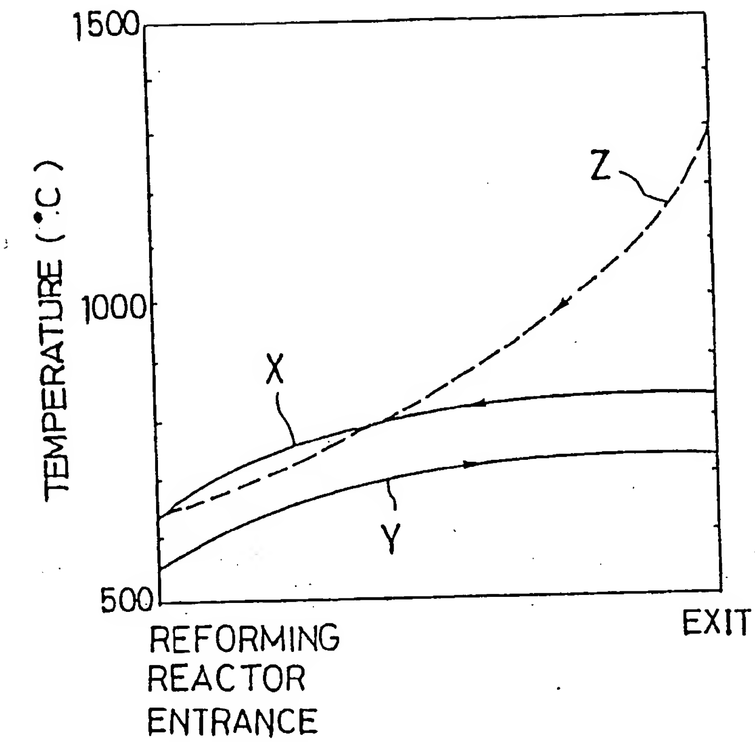
Z
X
Y
REFORMING
REACTOR
ENTRANCE
EXIT

FIG.4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X
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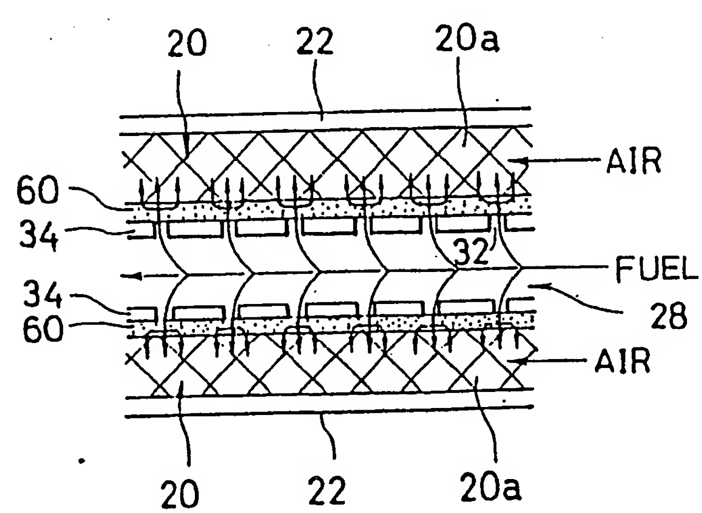
REACTOR
ENTRANCE
EXIT

FIG.5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AIR
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32
FUEL
34
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AIR
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22
20a

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EUROPEAN SEARCH REPORT

Application number

EP 88115740.8

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
Y	JP - A - 62-160 134 (ISHIKAWAJIMA-HARIMA) * Fig. 1 * --	1-10	C 01 B 3/34 B 01 J 8/02
Y	JP - A - 62-160 135 (ISHIKAWAJIMA-HARIMA) * Fig. 1 * --	1-10	
Y,D	JP - A - 62-160 136 (ISHIKAWAJIMA-HARIMA) * Fig. 1-3 * --	1-10	
A	JP - A - 62-27 305 (ISHIKAWAJIMA-HARIMA) * Fig. 1-3 * ----	1	

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

C 01 B 3/00
B 01 J 8/00

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	24-11-1988	MARCHART

CATEGORY OF CITED DOCUMENTS

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